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Final Report for Rm 28-C2-267

A STUDY ON YIELD SIMULATION APPLICABLE TO DWARF MISTLETOE INFESTED, IRREGULAR PONDEROSA PINE STANDS

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June 15, 1984

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Final Report for Rm 28-C2-267; A Study on Yield Simulation Applicable to Dwarf Mistletoe Infested, Irregular Ponderosa Pine Stands

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SUMMARY

Preliminary assessment, compilation of Front Range and Southwestern data, a Southwestern field reconnissance and an evaluation of Stage II inventory data for the Front Range has been completed. Insufficient data is available to clearly define the effect of mistletoe infection on the growth of irregular ponderosa pine stands. A sampling design and field plan have been developed to obtain the necessary additional data to define the relationships.

RESULTS COLORADO PLOTS

Plot Description

The Colorado plots established earlier by Hawksworth were of a fixed area and ranged from .54 to 1.25 acres in size. The number of stems per plot ranged from 137 to 228 with an average of 184 live stems. The plots were located throughout the Pike/San Isabel and the Arapahoe/Roosevelt National Forests and encompassed a fairly wide range of stand conditions and severity of mistletoe infestation. Site indices, stand basal area, and average height ranged from 36 to 60, 39 to 122 sq ft per acre, and 18 to 34 ft, respectively. Stand DMR ranged from 1.0 to 5.5 (Table 1).

Basal areas, 5 and 10 years previously, were approximated on the basis of past diameters of live and dead trees. Regression equations of present

heights over diameters by plot were used to estimate past heights (Table 2 and 3). Histograms of diameter distributions were also constructed for present stand conditions and mortality over the past 10 years. There seemed to be two types of diameter distributions on the Colorado plots;stands with predominantly small trees (positively skewed) and stands where numbers of individuals within various diameter classes were distributed more evenly. There were no bimodal distributions nor was there any obvious association of either of the two distribution types with any of the stand parameters measured or with any level of mistletoe infection. Diameter distributional patterns ~~in mortality~~ of dead trees also could not be correlated with stand parameters. Mortality, however, was significantly related to the level of mistletoe infestation and occurred most frequently in the 1 to 7 inch size classes.

Stage II Inventory Analysis

Stands were selected from Stage II inventory data to detemine, in'general, the characteristics of irregular mistletoe infested ponderosa pine growing along the Front Range and to compare them with the 18 plots. Stands selected had to be classified as ponderosa pine stand types by the Stage II and have at least a 12 inch diameter distribution of ponderosa pine. Further, this 12 inch distribution had to be fairly continuous, not, for example, 500 one-inch size trees and one 18-inch tree. Stands also had to have mistletoe present to be selected.

Once stands were selected mean site indices, dbh's, basal areas, and heights were calculated. DMR was not given for most of the inventory stands. Instead only the presence or absence of mistletoe was recorded. Therefore, the average severity of mistletoe infestations could not be calculated from Stage II data.

Data was first pooled and averages of the stand parameters were generated for the entire Front Range (Table 4). The data was then stratified by forest (Table 5), by district and average values were computed on the basis of these divisions. All averages were calculated by weighting the acre size of each contributing stand relative to the sum of the acres of all the stands. Variances were also calculated proportional to stand size.

The Stage II data showed that, in general, site index is relatively low. However, site index may be slightly underestimated since it was not specifically collected and had to be extrapolated from average height/age relationships rather than from the height and age of the co-dominants. Average dbh does not appear to differ much between forests and average height and basal area were somewhat higher on the better sites of the Pike/San Isabel.

Analysis of Mistletoe and Growth

The 18 Colorado plots were used to study mistletoe/growth relationships. Diameter growth, 5 and 10 years previously, was estimated by taking a core from each tree and measuring the growth rings. A regression equation, developed by Myers and Van Deusen 1958, was then used to estimate past DBH from the width of the rings. Since the regression equation only applied to trees with a DBH of two inches (or greater) at the time of measurement, trees with smaller diameters were temporarily eliminated from the analysis. There were very few trees under two inches.

Diameter growth effects were analyzed on a plot by plot basis to initially remove the effect of site index and stand basal area. Results of regression -- graphical analysis indicate the following:

1) Competition is the most apparent factor influencing diameter growth of live trees since larger trees seem to be growing faster than the smaller trees. Trees on all plots (both infected -- and uninfected trees), exhibited a significant positive linear relationship between past girth and present growth. The variable best describing (accounted for the most variance) this allometric relationship was basal area (a transformation of diameter growth). Coefficients of correlation from linear regression of basal area growth over basal area ranged from .05 to .53 with an average variance reduction of 33%. Because the variance of the linear regression of basal area and past basal area was unequal (variance increased with increasing basal area), a natural log transformation was performed on basal area and basal area growth to correct for this problem. As a result, correlation coefficients changed somewhat on a per plot basis, but overall percent reduction in the variance remained essentially unchanged (remained 33%).

2) More data is needed to clarify the growth effects of mistletoe infestations. The relationship of individual tree growth to level of mistletoe infection is not clear. Linear regression -- and graphical comparisons of healthy and lightly infected trees (DMRs of 0, 1 and 2) to heavily infected trees (DMRs of 5 and 6) were inconclusive. Nineteen percent was the most that DMR as a dependent variable in a regression was found to reduce the variance. The average reduction of the variance was 5%, four plots having non significant relationships, (P>.05)

(this reduction in variance occurred for plot 1 when trees with DMRs of 0, 1 and 2 were grouped and linear regression applied). A possible reason for this apparent lack of relationship may be diameter differences between trees (the effects of competition) have not been completely removed from the analysis and are still confounding the effects of mistletoe on growth. Small differences (i.e., place in canopy) in average diameter in each of mistletoe infection class exist for most plots or unequal mortality rates in the different size classes could be the source of the conflicting results. The best way to eliminate this problem may be to divide the trees on each plot into, at the largest, 4 inch size classes and then examine the effects of mistletoe. Unfortunately, there are not usually enough representatives from each size/DMR class to clearly define growth relationships and stand conditions across plots may vary too widely to justify pooling plots at this point. In other words, stands vary so widely that pooling may further confuse rather than clarify mistletoe/growth relationships. Another approach could be to compare growth of trees by diameter classes on paired plots of the same size and origin (hopefully located side by side). Pairing would consist of light or uninfected with moderate to heavily infected plots. The sampling design developed for the collection of further data will make this type of growth comparison possible. This pairing may also show how diameter class distributions shift (both in % and number of individuals) as the stand becomes increasingly more heavily infected.

SOUTHWESTERN PLOTS

Bryce Canyon

Five permanent mistletoe plots were established in irregular stands in Bryce Canyon National Park in 1952. These plots were located and evaluated for possible use in this study. One was found to be unusable as a campground had been established in it. Four plots were undisturbed, but two of these were mixed species and, therefore unsuitable. The two remaining single species plots may be valuable in providing long term measurements of growth and DMR since they closely approximate lower site indices stands in the Front Range. These plots will not be used in the current study of ponderosa pine in the Front Range.

Grand Canyon

All six permanent plots on the South Rim of the Grand Canyon were inspected. The stem map for plot -- was updated and height measurements were taken for plot 2 (treated) (previously heights had been estimated from past year measurements). Plot 6 was found to be only partly irregular. Some areas were regular and some two storied. It will, therefore, be necessary, if plot 6 is to be used for studying irregular stands, to delimit the irregular sections of the plot. Since ingrowth has not been measured in plot 6, it will also be necessary to measure ingrowth and add it to the data set if lthis is to be used at some time in the future (Table 6).

The North Rim of the Grand Canyon was also visited. It appears that the stands on the North Rim are slightly different in the 'irregularness' than those on the South Rim (the even size patches are much smaller, in other words these stands are more uniformly irregular), indicating a

broader range of data also needs to be gathered for the Southwest to model the irregular ponderosa stands.

FUTURE WORK

A field manual was written delineating sampling effort to model irregular ponderosa pine stands infested with dwarf mistletoe along the Front Range of Colorado (Figure 1). The manual is currently being used.

LITERATURE CITED

Myers, C. A. and J. L. Van Deusen. 1958. Estimating past diameters of ponderosa pines in the Black Hills. USDA-USFS Res. Notes 32. 2 pp.

Table 1. Stand conditions for Colorado Front Range Plots at time of measurement.

PLOT	BASAL AREA	SITE INDEX	DBH	HEIGHT	DMR
801	70	46	6.6	27	5.1
802	56	49	5.2	20	2.6
803	39	36	4.6	18	4.8
804	61	49	6.5	30	4.3
805	81	44	6.5	23	4.3
806	78	47	4.8	18	5.6
807	107	58	6.7	33	3.4
808	122	50	5.0	24	2.8
809	88	49	5.5	24	3.4
810	53	60	7.0	28	4.3
811	53	51	5.9	24	3.9
812	61	51	6.2	27	2.9
813	44	54	6.7	25	4.3
814	83	48	7.6	32	4.1
815	56	43	4.4	18	1.4
816	50	56	4.6	21	1.2
817	50	55	7.9	31	2.7
818	104	58	8.0	34	2.2

*Basal Area is in sq ft

**Height and DBH are in ft and inch, respectively

***DMR includes all measured trees

RANGE OF DATA

Basal area	39-122
Site index	36-60
DBH	4.4 - 8.0
Height	18-34
DMR	1.2 - 5.6

Table 2. Estimated stand conditions for Colorado Front Range Plots 5 years before measurement.

PLOT	BASAL AREA	SITE INDEX	DBH	HEIGHT
801	71	46	6.2	30
802	51	49	4.8	19
803	44	36	4.6	18
804	67	49	6.2	28
805	80	44	6.1	21
806	79	47	4.6	17
807	106	58	6.3	31
808	118	50	4.8	24
809	84	49	5.4	24
810	40	60	6.3	24
811	55	51	5.2	21
812	61	51	5.8	27
813	43	54	6.1	23
814	84	48	7.0	29
815	57	43	4.4	18
816	50	56	4.5	20
817	66	55	7.9	31
818	103	58	7.8	33

*Basal Area is in sq ft

**Height and DBH are in ft and inch, respectively

***DMR includes all measured trees

RANGE OF DATA

Basal area	40-118
Site index	36-60
DBH	4.4-7.8
Height	17-33
DMR	

Table 3. Estimated stand conditions for Colorado Front Range Plots 10 years before measurement.

PLOT	BASAL AREA	SITE INDEX	DBH	HEIGHT
801	72	46	5.9	23
802	49	49	4.5	18
803	45	36	4.5	17
804	71	49	6.0	26
805	79	44	5.9	20
806	76	47	4.2	15
807	115	58	6.0	29
808	115	50	4.6	23
809	79	49	5.0	22
810	38	60	5.9	23
811	54	51	4.6	18
812	58	51	5.4	25
813	42	54	5.6	21
814	86	48	6.8	28
815	52	43	3.9	16
816	41	56	3.7	18
817	59	55	7.3	27
818	98	58	7.2	31

*Basal Area is in sq ft

**Height and DBH are in ft and inch, respectively

***DMR includes all measured trees

RANGE OF DATA

Basal area	38-115
Site index	36-60
DBH	3.7-7.3
Height	15-31
DMR	

Table 4. Weighted averages and variances of selected stand parameters derived from Stage II inventory data for mistletoe-infected irregular ponderosa pine along the Colorado Front Range (pooled for all of Front Range).

# Acres	Basal areas (sq ft)		Site index (ft/100 yrs)		DBH (in)		Height (ft)	
	$\bar{X}$	S^2	$\bar{X}$	S^2	$\bar{X}$	S^2	$\bar{X}$	S^2
6929	63	353	45	43	9	3	33	39

Table 5. Weighted averages and variances of selected stand parameters derived from Stage II Inventory Data for mistletoe-infected irregular ponderosa pine along the Colorado Front Range (stratified by forest).

*Forest	# Acres	Basal area (sq ft)		Site index (ft/100 yrs)		DBH (in)		Height (ft)	
		X	S^2	X	S^2	X	S^2	X	S^2
Roosevelt	3138	61	215	44	11	9	1	32	27
Pike	1748	73	331	50	37	9	4	35	37
Arapahoe	1728	58	505	42	65	8	5	31	44
San Isabel	315	69	172	50	19	10	7	38	87

*Assuming Pike/San Isabel and Arapahoe/Roosevelt combinations are separate forests.

Table 6. Ponderosa pine irregular permanent plots in the southwestern United States.

Location	Plot No.	Type	Size (Acres)	Stem Map
Grand Canyon - Arizona				
(established 1950)	1	check	10.00	yes
	1	treated	10.00	yes
	2A	check	1.25	yes
	2B	check	1.05	yes
	2	treated	2.62	yes
	6	check	4.80	yes
Mescalero - New Mexico				
(established 1949-1950)	1		10.00	yes
	2		10.00	yes
	3		10.00	yes
	4		11.00	yes
Ft. Valley Exp. For. Arizona				
Hatfield				
(established 1933)			19	no
Wing Mtn.				
(established 1939-1974)	4 plots		64	no

Figure 1. Growth and yield relationships in mistletoe infected - irregular pondesrosa pine stands on the Colorado Front Range. 1984. Field Manual prepared by Helen M. Maffei, Dept. of Plant Pathology, Colorado State University, Cooperative Agreement RM 28-C2-267.

This manual describes procedures used in the 1984 collection of field data. The purpose of collecting this data is to obtain the information necessary in order to quantify growth and yield relationships in dwarf-mistletoe infected, irregular ponderosa pine stands on Colorado's Front Range. Specific relationships to be studied are:

1. the effect of the size of a tree on its future growth
2. the effect of increasing degrees of severity of mistletoe on future tree growth
3. the effect of site quality on tree growth
4. the effect of tree position in relation to its neighbors on future growth

Information collected during this field season will be recorded on two card types and two corresponding data forms (Appendix).

Card type 1:

Plot number	Plot area	Elevation	Date	Topography
Site index	Aspect	Stand-compartment		Habitat type
Township	Range	Section		Crew

Card type 2:

Plot number	DMR	Height	Competition Class
Growth last 5 and 10 years		Damage	When the tree died
Broom rating	The presence or absence of decay		

All data on this card (except plot number) will be read in as numerical values (either real or integer). Data item definitions and codes are given in the appendix.

Sampling design

Relative definitions for sampling designs:

	high	moderate	low
Basal area	120-140	50-80	24-50
Site index	60-70	45-60	40-45
DMR	1-2	3-4	5-6

Sampling Design

stratification

district	Pike Roosevelt	=2
		x
basal area	high, low	2
		x
site index	high, low	2
		x
DMR	high-low, low-med	2
		x
rep	(if time permits)	2

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Note: Because the Arapahoe and the Roosevelt appeared (from the Stage II data) not to differ significantly for the stand conditions used in stratifying, they will be pooled together as will the Pike and the San Isabel. Hawksworth's 17 plots will be paired (if possible) as part of the required number of plots. This pairing will be done first (along with the already located Roosevelt plots at Arthur's Rock and in Glen Haven). The Arthur's Rock and Glen Haven locations will account for the low site index, high basal area and high and medium mistletoe infestations x 2 reps.

The reason plots are being paired is to provide a check plot to evaluate the effects of mistletoe. The idea is that each plot of the pair regenerated at the same time under similar conditions and have been subjected to similar disturbance and microclimatic conditions since that time with the exception of different levels of mistletoe infection.

Time Sequence for Sampling

Spring break - locate several Roosevelt-Boulder plots

May 15-June 1 - sample Arthur's Rock and Glen Haven plots

June 2-June 30 - locate and sample remaining Roosevelt plots; look for pairs that will correspond to Hawksworth's already existing plots first

July 1-August 15 - locate and sample Pike plots. Again, look for pairs for Hawksworth's plots first.

APPENDIX

Data Form 1

Column

1-3	plot number column
4-8	date (example: 122056)
9-13	plot area column (in sq ft to the nearest ft)
15-20	slope (to be entered as degrees)
21-23	site index - to be determined by coring a site tree at stump level, and using the site index curves in the Stage II manual. Site trees should be chosen according to the guidelines in the Stage II manual (tree still putting on height growth, vigorous and non-suppressed, free from growth affecting insect and disease infestations).
24-26	aspect-put in as degrees, north = 0. blank = none
27-36	habitat type
37-47	stand - compartment number, if on private land a 0 is substituted in column 20 and the rest are left blank
48-57	township, range and section
58-66	crew members initials

The purpose of the section line of data form 1 is to provide more information as to the location of the stand, when the data was collected and who collected it. The purpose of the habitat type notation is to make sure the paired plots on comparable sites.

Data Form 2

Column

1-3 plot number column

5 DMR column - species other than ponderosa pine are also identified in this column. 7 = Douglas fir, B = aspen, 9 = juniper

6-8 tree number column - trees are numbered consecutively within plots.

9-12 DBH column - trees will be measured at 4.5 feet to the nearest 1/10 of an inch and recorded as a decimal on the data form.

13-16 Height column - trees will be measured to the nearest foot. Competition class column - this is a classification of trees based on dominance in relation to adjacent trees and available light (based with some modifications on the Stage II guidelines for crown class ratings)

17 third of the canopy crown of tree occupies 1 = top 1/3, 2 = middle 1/3, 3 = bottom 1/3

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Code	Description
0	Open grown - trees with crowns which have received full light from above and from all sides for the last 5-10 years of the tree's life
1	Dominant - trees with crowns receiving full light from above and partly from the side, usually larger than the average trees in the stand, with crown that extend above the general level of the canopy and are well developed

2 Codominant - trees receiving full light from above, but comparatively little from the side, crowns usually form the general level of the canopy (for the last 5-10 years)

3 Intermediate - trees receiving little direct light from above and none from the sides, trees visibly stretching for light where release is still possible

4 Overtopped or suppressed - trees receiving no direct light, and where release is impossible

19-22 Age column - every third tree will be aged at DBH

23-25 Growth, last 5 and 10 years, respectively. One core will be taken on the south side of the tree and ring width will be measured to be the nearest 1/50 of an inch (this measurement will be recorded as a decimal on the form)

29-31 Damage column -

1 in column 29 - a tree is classified as 'bonsi' when the height/crown width ratio is approximately 1 (or less) and when this condition has been caused by past (or present) suppression. Significant apical growth is impossible since the terminal leader has been killed

1 in column 30 - a tree is classified as 'down' when its entire crown is bent below the bottom of the crows of surrounding trees. Rainbow trees fall into this category

1 in column 31 - a tree is classified as having a 'dead top' if the terminal leader is killed and the tree not classified as a 'bonsi.'

42 5 or 6 in this column is the tree dies 5 or less, or from 6-10 years ago, respectively

Guide for estimating time since death (based on Stage II specifications) (with some modifications):

Died within the past 5 years	Species	Died 6-10 years ago
possibly some foliage left 50% + twigs left most branches left	Ponderosa pine	no foliage left at least 50% bark left 50% or less twigs and branchesmost bark left

The presence of Fomes pinocola will be accepted as evidence that the tree has been dead more than 5 years.

44 Decay column - if decay is present put a 1 in this column.

FIELD PROCEDURES

1. Before going out, make sure that all necessary supplies are in the car.
2. Check the oil, tires, etc. to make sure there are no obvious mechanical or safety problems. Clean the windows if necessary. Make sure the following items are in the car: shovel, pliers, jumper cables, wire, duct tape, first aid kit and chains.
3. Find the plot.
4. Perform a quick check with the prism to make sure that the basal area is close to what you thought it was before you choose the plot. Also core (at stump line) and count the rings on a site tree to verify site index. Record slope, aspect, elevation and plot location.
5. Delineate the two plots. One plot should have an average DMR of no greater than 2 and contain approximately 100 individuals. The other plot should be either moderately (DMR = 4-5) , or heavily infected (DMR = 5-6), depending on what has already been accounted for in the sampling plan. Both plots must be the same dimensions and fall on as similar topography as possible. Hopefully these paired plots will be side by side, and have the same habitat type.
6. After the plots have been delineated, numbered index cards should be stapled onto each tree (living and those having died less than 10 years ago). The cards should be stapled at the corners to facilitate recycling. As the cards are being stapled to the trees, one person should start taking 5 and 10 year growth of each labeled living tree. This will be done by taking bores at DBH with an increment bore, and putting the core in a labeled straw. The ends of the straw will be

stapled shut. On every third tree the core should go to the center of the tree since the core will also be used to age the tree. Cores that are being used to age the trees should be labeled as such on the straw.

7. After all the trees have been labeled, two persons (working together) will take heights, dbh's, broom ratings and fill in the damage columns (recorder). Helen will take competition class ratings and Karen Ogle habitat types. Whomever gets done first will help the others finish.
8. Remove the tags from the trees.

LAB PROCEDURE FOR COLLECTED FIELD DATA

1. Cores taken in the field will be stored until they can be measured in the lab. The growth measurements will be taken to the nearest 50th of an inch but and recorded on the data form as a decimal fraction.

SUPPLIES NEEDED FOR FIELD WORK

(things not to forget)

1. data forms and field instructions, clipboard/tadem
2. pencils
3. 400 plastic straws
4. waterproof (and smearproof) magic markers
5. 2 increment borers
6. 1 increment hammer (not essential)
7. 2-dbh tapes, in inches not metric
8. 200 foot measuring tape
9. small paper bags for straws

10. numbered 1-300 index cards
11. cruiser vests for all workers
12. string, stakes, flagging
13. 2 clinometers
14. 2 loggers' tapes (spring loaded retractable measuring tape), 2 refills
15. staple gun, staples, stapler, stapler
16. plastic bags (one big enough to fit over field forms)
17. RAF 10 prism
18. Map
19. compass
20. altimeter
21. axe
22. hand lens
23. camera
24. height plot (not essential)
25. plastic ruler
26. razor blades
27. spray paint
28. binoculars (not essential)
29. bottle ETOH (to clean measuring tapes)
30. knife
31. habitat-key and flora
32. gun cleaning kit and 10-40W oil to keep borers clean
33. raincoats, lunch, etc.

#15.
stapler,
staples
?